BROADBAND CHARACTERIZATION OF TRANSIENT ANTENNAS

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Abstract

The application of pulsed power to transient RF/microwave generation for warhead/projectile payloads is currently a significant research area. In this application, traditional fixed antenna designs have two major drawbacks: the size required for efficient radiation can be prohibitive for frequencies much less than 1 GHz, and the fixed antenna can make the device vulnerable to electromagnetic counterattack. One frequently proposed solution to both issues is the use of transient antennas. To effectively integrate these devices, the various types of transient antennas must be characterized over a wide frequency band during their transient formation period. A testing method being developed at the Center for Pulsed Power and Power Electronics at Texas Tech University utilizing a broadband transmitter and receiver is described.

I. INTRODUCTION

The application of pulsed power to transient RF/microwave generation for warhead/projectile payloads is currently a popular area for research. A central part of this work involves the antenna systems to be utilized in these devices. For this application, traditional fixed antenna designs have two main drawbacks: the size required for efficient radiation can be prohibitive for frequencies much less than 1 GHz, and the fixed antenna can make the device vulnerable to electromagnetic counterattack. One possible solution to both issues is the use of transient antennas, or antennas that exist only for the short period of time that the device is in operation (microseconds to milliseconds). The device is then protected from external EM attack, and the problem of attaching a large fixed antenna to a projectile is avoided. The development of effective testing methods to apply during the transient formation and dissipation of these devices is needed to facilitate their integration with pulsed power transmitter payloads.

II. BACKGROUND

Several methods for generating transient antennas have been previously studied. Some of these include methods where the antenna is made up of a plasma (created by a laser, created by an explosively driven plasma jet [1], or created inside a non-conductive tube) or a conductive material (such as in the metal jet from an explosive shaped charge [2]). These devices can be prone to breakup due to instabilities or stretching of the antenna. In order to be an effective resonant antenna, there must be electrical continuity along its entire length. Methods are needed to experimentally evaluate RF parameters such as resonant frequency, gain and bandwidth, during antenna operation.

Evaluations of transient antennas have previously been performed at fixed frequencies [1], [2]. For example, testing was previously performed at Texas Tech on an explosive-driven shaped charge conductive jet at a fixed frequency of 1GHz. While valuable, such a test provides a limited amount of information about the antenna performance. Ideally, a test method would be developed to perform a broadband measurement of the antenna during its limited lifetime. This would allow the full measurement of antenna parameters with a minimum of experimental shots.

Pulsed power-driven RF generators in the frequency range less than 1GHz typically do not have a single fixed output frequency. Transmitter types under consideration would more likely output a single frequency changing with time (chirp transmitter) or a broad output spectrum. A broadband characterization of an antenna design would allow the development of multiple applications with minimal additional testing. A measurement concept has been developed involving the use of a broadband (noise) transmitter connected to the transient antenna, with a corresponding broadband fixed receiving antenna to measure the transmitted power. This experimental setup should allow the simultaneous measurement of antenna parameters across frequency during antenna operation.

III. TRANSIENT ANTENNA PARAMETERS VERSUS FREQUENCY

The primary parameters that are required to utilize an antenna of this type (assumed to be a resonant monopole

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14. ABSTRACT
The application of pulsed power to transient RF/microwave generation for warhead/projectile payloads is currently a significant research area. In this application, traditional fixed antenna designs have two major drawbacks: the size required for efficient radiation can be prohibitive for frequencies much less than 1 GHz, and the fixed antenna can make the device vulnerable to electromagnetic counterattack. One frequently proposed solution to both issues is the use of transient antennas. To effectively integrate these devices, the various types of transient antennas must be characterized over a wide frequency band during their transient formation period. A testing method being developed at the Center for Pulsed Power and Power Electronics at Texas Tech University utilizing a broadband transmitter and receiver is described.

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or dipole) are the resonant frequencies, the bandwidth at those frequencies, the radiation pattern, and the feed impedance. All of these parameters depend directly on the size and shape of the antenna, and must be matched to the source for efficient operation. A complete characterization of a transient antenna would involve measurement of these parameters across frequency as the geometry of the antenna changes in time.

The antenna parameters vary widely across frequency. Figure 1 shows the calculated impedance as a function of the ratio of the antenna length to the wavelength for two different fixed cylindrical antennas. Figure 2 shows some theoretical antenna patterns vs. frequency. In this work, we will consider the gain in the (theoretical) direction of greatest directivity, instead of the entire radiation pattern.

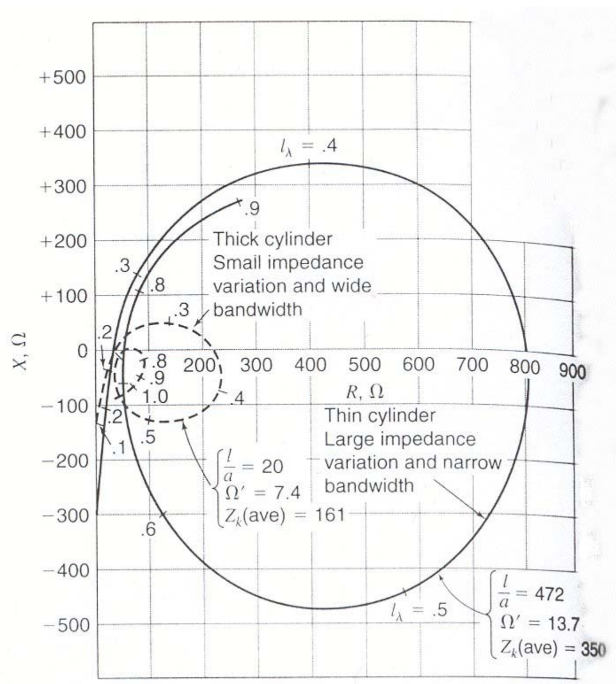

Figure 1. Monopole feed impedance across frequency for two different length-to-radius ratios, from [3]. The real part of the impedance is on the x-axis, the imaginary on the y-axis. The length of the antenna is referenced to the wavelength along each curve. The length-to radius ratio for the solid curve is 472, and 20 for the dashed curve.

Figures 1 and 2 demonstrate the wide variations in antenna patterns across frequency, for different antenna sizes and shapes. These graphs are for cylindrically-shaped antennas, which have been well-characterized across frequency. This data is not as well characterized for other shapes (for example, conical). If the shape that a transient antenna develops into during operation is not known exactly, it can be very difficult to predict RF performance without making experimental measurements. The antenna shape for different devices can range from a large length-to-radius ratio to a small ratio, to even conical shapes. All of these variations can change the resonant frequency and bandwidth of the antenna.

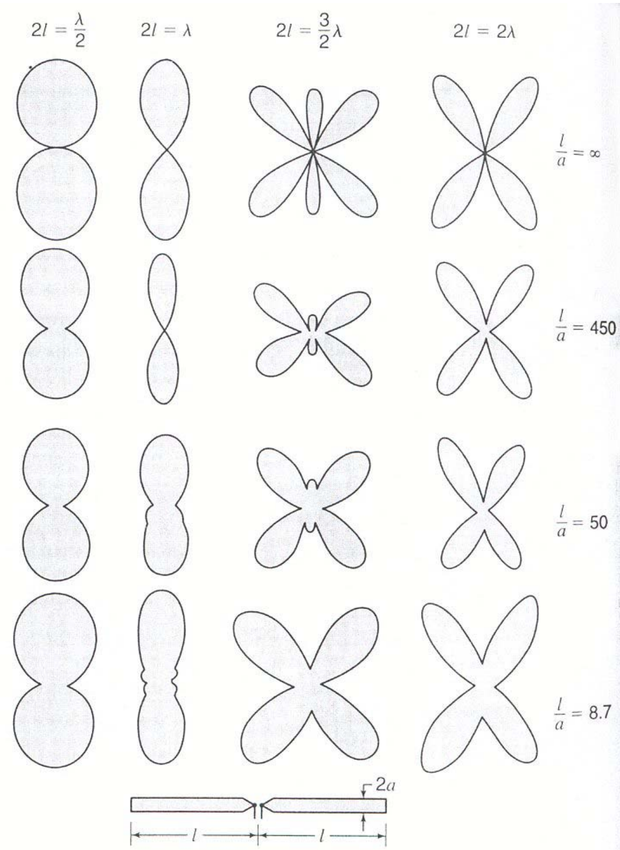

Figure 2. Dipole antenna patterns versus length and length-to-radius ratio, from [3].

IV. EXPERIMENTAL SETUP AND FIXED MEASUREMENTS

Using a broadband (noise) transmitter connected to a transient antenna and a broadband receiving antenna will allow the direct measurement of the relevant antenna parameters with respect to time. The frequency spectrum of the received signal over a certain time window will show the power radiated versus frequency at that time. The power received at a frequency at a certain point in time will depend on the transmitter's impedance match to the antenna at that frequency and the antenna's gain at that frequency in the direction of the receiving antenna.

For the broadband transmitter, an amplified noise source (model NC1109A from Noise Com, Inc., 100Hz to 1GHz, +10dBm output) is connected to a broadband amplifier (model TIA-1000-1R8 from Mini-circuits, 35dB gain, 0.5MHz to 1GHz, 4W max power output), and then to the antenna through a broadband matching transformer (model ADT1.5-17 from Mini-circuits, 1.5:1 impedance ratio, 0.5MHz to 1.7GHz) to match the 50 ohm system to the resonant monopole impedance of 36 ohms. To protect the amplifier from a high voltage standing wave ratio on the output, the noise source power is attenuated by 20dB, and a 3dB attenuator is added to the output of the amp.

For the broadband receiver, a commercial wideband receiving antenna is used: the EM-6917B-1 biconicalog (combination bi-cone and log-periodic) antenna from Electro-Metrics. This is a wideband antenna intended for EMI / EMC testing. This antenna is seen in Figure 4. The antenna output is factory calibrated from 30MHz to 3GHz. For a transient measurement shot, the received data will be captured using multiple Agilent Infiniium oscilloscopes. A Fourier Transform will be applied to the time data over a window of a certain length, to look at the frequency domain behavior across time.

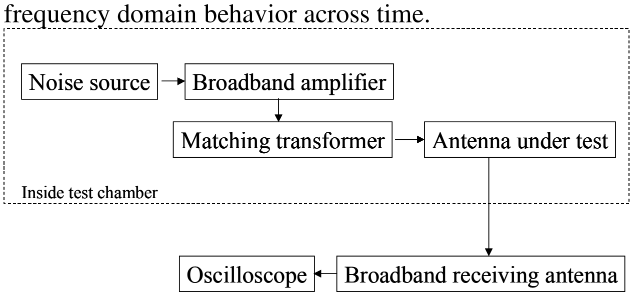

Figure 3: Block diagram of measurement setup

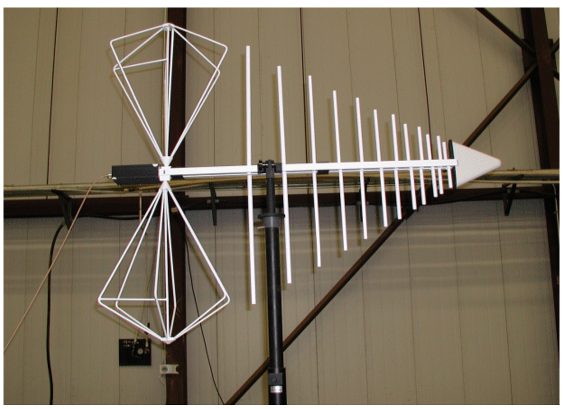

Figure 4: EM-6917B-1 biconicalog wideband antenna

There are several practical problems associated with this measurement. The magnitude of the power received must be greater than the background noise across the frequency band. The signal must be measured with enough time resolution to capture the desired bandwidth, and it must be measured over the relatively long operation period of the antenna. This will require either an oscilloscope with an extremely long record length, or multiple scopes triggered in sequence. The window width of the FFT must be wide enough to ensure adequate resolution in the frequency domain. All of these issues are being addressed in the initial feasibility testing currently being carried out.

A new explosive testing chamber is under construction at the Center for Pulsed Power and Power Electronics Research at Texas Tech University. The previous testing done at Texas Tech [2] was carried out in a smaller steel chamber, making it difficult to quantitatively measure antenna parameters. The new chamber is constructed with large windows to allow for RF propagation. The new setup is shown in Figure 5, along with the broadband receiving antenna. The chamber is constructed from steel reinforced concrete, so the radiation from an antenna inside the chamber to the receiver outside the chamber will differ somewhat from measurements/simulations done in the open air.

Figure 5: Explosive testing chamber and broadband receiving antenna

Baseline measurements of the radiation from fixed antennas inside the chamber versus simulation and open-air results will be made once the chamber is complete. The testing will concentrate on the simplest case of single horizontally polarized monopole antennas, with a ground plane. This testing will be intended to develop a procedure for extrapolating the test results to open air performance. Initial feasibility measurements of this type have been made, with the results in Figures 6 through 9.

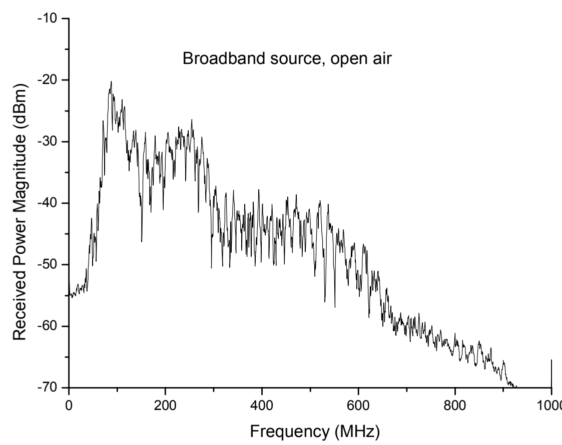

Figure 6: FFT of received signal using fixed antenna (0.75 in. diameter x 30 in. length), in open air

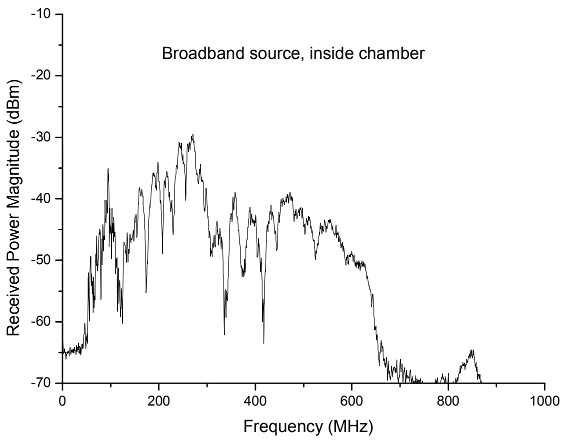

Figure 7: FFT of received signal using fixed antenna (0.75 in. diameter x 30 in. length), inside chamber

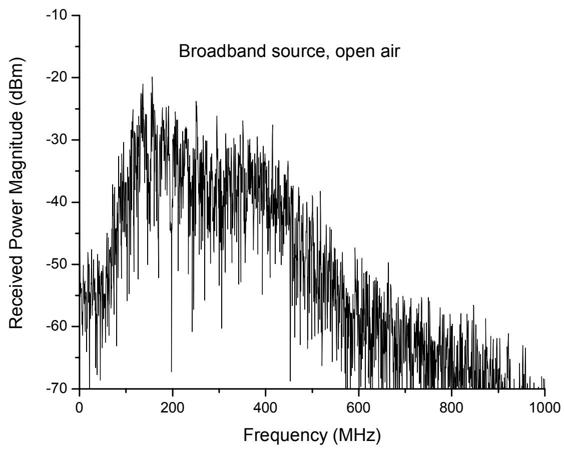

Figure 8: FFT of received signal using fixed antenna (0.75 in. diameter x 16 in. length), in open air

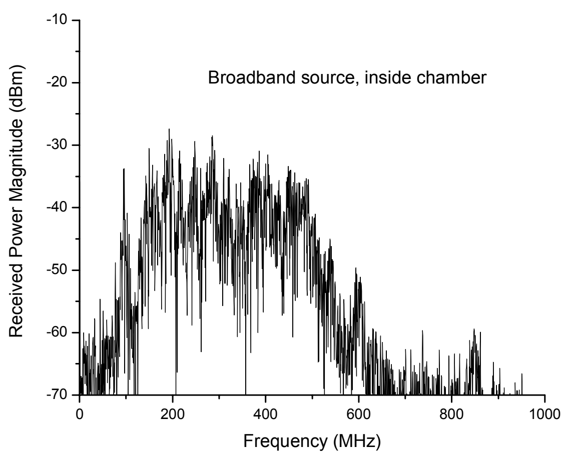

Figure 9: FFT of received signal using fixed antenna (0.75 in. diameter x 16 in. length), inside chamber

The separation between the transmitter and receiver for all of these measurements was four meters. The power received from the broadband source was typically at least 20dB above the background noise (commercial FM radio stations). The initial measurements shown were made using fixed antennas that were 0.75 inches in diameter, and 16 inches or 30 inches in length.

Figures 6 through 9 were recorded using the broadband source as the transmitter, and recording the signal with an oscilloscope, as would be done in a transient shot. The displayed waveform is the FFT of the received signal. Figures 6 and 7 (antenna length 30 inches) were averaged over many individual captured waveforms, while Figures 8 and 9 (antenna length 16 inches) show the FFT of a single captured waveform. These graphs demonstrate the difference between the measured antenna performance in the open air, and inside the test chamber.

V. CONTINUING RESEARCH

Once the test chamber is completed, further fixed antenna testing will be done to characterize the differences between the radiation measurements in open air and in the chamber. The experimental setup will then be ready for transient antenna testing.

VI. REFERENCES

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